if any food adulterant runs more than a short course now, the fault must be charged to inefficient food laws.

Let us protect the honest manufacturer and dealer at every point against the unfair competition of dishonest rivals. Let our products stand on their own merits—stand or fall. And let the same rule apply to imported goods.

I have tried to obtain refined cottonseed oil from our leading grocers, but have rarely succeeded except at four times its value and under another name. Our native wines, superior to the common wines of any other country, are creating for themselves an increasing demand in foreign countries under their proper labels. Why, then, should we allow them to receive fictitious names at home? Let us by all proper means promote the use of American maize at home and abroad, but always as maize —not as wheat! Let us eat plain American herrings, if we choose, but not 'French sardines' from the coast of Maine. Let us stop the sale of 'pure imported Lucca oil' from the cotton fields of Georgia. Whether as a matter of morals or from policy, let us have honesty.

W. D. BIGELOW.

COLOR VISION.

OF late years the subject of color vision seems to have been specially stimulating to students of psychology, if a judgment may be based upon the rapid increase in the number of hypotheses advanced to explain it. The last of these is briefly outlined in a recent issue of SCIENCE (Feb. 18, 1898), having been brought forward by Professor Patten, of Dartmouth College, at the meeting of the American Physiological Society during Christmas week, and based upon his observation of the fibrils in the eyes of invertebrates. On the assumption "that the length and angular relations of a fibril determine the amount of its response to a wave of light of a given length and plane of vibration, it is possible to offer a logical explanation of many phenomena of color vision."

Every investigator recognizes the necessity of hypotheses as antecedent to theories. The contrast between these may be briefly expressed in the definition of Flourens: "A hypothesis is the explanation of facts by possible causes; a theory is the explanation of facts by real causes." The wave theory of light was a hypothesis until it became fortified by a mass of evidence, mathematical and experimental. The most important single experiment was that of Foucault, who showed that on passing from air into water the velocity of propagation of light is diminished, as it should be according to the wave theory, while according to the emission hypothesis it should be increased. This crucial experiment alone would have been sufficient to change the wave hypothesis into a wave theory. Professor Patten's view of color vision is announced as a 'new theory.' This word is, indeed, so generally employed as a synonym for hypothesis that it may, perhaps, be as well to accept the mandate of usage, insisting always, however, upon a distinction between established and unproved theories. No existing theory of color vision has been established upon evidence comparable with that on which the wave theory of light rests. This fact should not prevent psychologists from forming and testing new hypotheses; but when there is so large a number of these offered for choice in relation to a single subject all persons other than the originators have good excuse for conservatism. Any one whose domain is not psychology should be content with indefinite suspense of judgment until psychologists quite generally agree upon one theory of color sensation, as physicists have agreed upon one theory of propagation of the waves which give rise to color.

Without a fuller statement than that recently given, it would be unfair to criticise Professor Patten's hypothesis. No physicist should criticise anything more than the assumption that the length and angular relations of a fibril determine the amount of its response to a wave of light of a given length and plane of vibration. To be valid the assumption should imply that each fibril has a definite rigidity in a definite plane so as to respond to special transverse vibrations. The subject scarcely offers a field for mathematical examination, and direct disproof is impossible. If this hypothesis is destined to outlive its announcement it must be because it is found to serve better than other hypotheses for the explanation of such troublesome visual phenomena as phosphenes, after-images and simultaneous color-contrast. Even if it should stand this test the physicist will probably be cautions about either attacking or sustaining it.

So far as the phenomena of physics are linked with those of sensation, it is natural that physicists should quite generally entertain a high respect for the conclusions reached by Helmholtz, an investigator who as a physiologist took rank with the most accomplished of his contemporaries, and whose brilliant work in physics can be judged by physicists more readily than that in physiology. When his important work on Physiological Optics was published, in 1866, the 'new psychology' was yet unborn. Even to-day it is not easy to assign a dividing line between psychology and the physiology of brain and nervous system. The hypothesis of color vision originated by Young, and revived after a half century by Maxwell and Helmholtz, has served a very useful purpose as a working hypothesis for physicists, and under present conditions it bids fair to serve them yet for a number of years in the same capacity. On such an extra-physical subject as sensation the physicist has scarcely any choice but to accept the consensus of opinion among the leaders in physiology and psychology. If the latter are irreconcilably at variance among themselves—and every new 'theory of vision' seems to emphasize this inference—the physicist must retain the working hypothesis which has been already found useful, however unsatisfactory it may be to those who are at variance. It may be perfectly legitimate for him to recognize, and even emphasize, what seems unproved in his working hypothesis, and thus openly profess his uncertainty. This cannot be greater than the uncertainty with which he would join some faction of the psychologists. If he wishes to test all the theories of color vision now offered him he must give up physics to a considerable extent and study psychology enough to become an investigator in this subject.

Without attempting to refute any one hypothesis of color vision, it may be sufficient to say that there are now at least seven of these presented as competitors for favor, four out of the seven having been announced during the last half dozen years. First is the Young-Helmholtz hypothesis; then comes that of Hering, which was its only competitor until 1887, when Wundt published his important paper entitled 'Die Empfindung des Lichts und der Farben.' In 1892 appeared Mrs. Franklin's 'Eine neue Theorie der Lichtempfindungen,' which was followed in 1893 by Ebbinghaus's 'Theorie des Farbensehens.' Still another competitor was brought forward by Nicati in 1895, to be followed in 1897 by the new American competitor just announced. The bewildered physicist is already a fit subject for commiseration, and apprehension about the future tends to make him yet more unhappy. He despairingly beseeches the psychologists to agree among themselves, but they will not agree; on the contrary, the prospect seems to be

that additional color hypotheses will continue to appear until from their abundance they cease to receive attention.

Competition is the normal condition of progress. 'Lernfreiheit' is, and must continue to be, the watchword of the student of science. In the evolution of psychology every hypothesis has a right to announcement. Whether it drops at once out of sight, or receives general and serious consideration, must depend upon its consistency as judged by those whose fitness to judge has been demonstrated. The workers in neighboring departments must content themselves with suspense of judgment until the result of the survival of the fittest is established.

Assuming, then, that in the present condition of disagreement among psychologists the oldest hypothesis of color vision is apt to continue in favor among physicists, it may be well to note a few points upon which we may be justly dissatisfied with it, these points being taken chiefly on physical rather than psychological grounds.

According to the Young-Helmholtz hypothesis in its modern form there are three fundamental color sensations, which may be expressed graphically by overlapping curves of intensity. The simultaneous excitement of all three in appropriate proportion gives the sensation of whiteness. The deficiency of the retina in capacity to respond to one or more of the stimuli corresponding to these sensations determines a special kind and degree of color-blindness.

This idea of fundamental sensations has a rather peculiar history, as was pointed out more than twenty years ago (*Am. Journal of Science*, April, 1875) by the late Professor A. M. Mayer. Dr. Thomas Young was a contemporary of Dr. Wollaston, the discoverer of the dark lines in the solar spectrum. Newton had considered the spectrum to be made up of seven colors. Of these red, yellow and blue were thought the most important, and were called primary colors, not with reference to any theory of color perception, but because by mixture of pigments of these three hues in suitable proportions all the other hues could be obtained, though with loss of purity and especially of brightness. These derived colors were, therefore, called secondary. This Newtonian view is thus not a theory of color vision in any proper sense. Young at first taught the Newtonian view, but subsequently changed his selection of primary colors on account of some erroneous observations made by Wollaston. In the Bakerian lecture, 'On the Theory of Light and Colors,' read before the Royal Society in 1801, under the heading 'Hypothesis III.,' Dr. Young wrote: "The sensation of different colors depends on the different frequency of vibrations excited by light in the retina." He further adds: "Now, as it is almost impossible to conceive each sensitive point of the retina to contain an infinite number of particles, each capable of vibrating in perfect unison with every possible undulation, it becomes necessary to suppose the number limited; for instance, to the three principal colors, red, yellow and blue, of which the undulations are related in magnitude nearly as the numbers 8, 7 and 6." He thus refers the production of color sensation to the covibration of special particles, set up by waves of special period, just as a tuning fork co-vibrates with another similar fork sounded in its neighborhood. He supposes that, like the tuning fork, 'each of the particles is capable of being put into motion, less or more forcibly, by undulations differing less or more from perfect unison,' and that 'each sensitive filament of the nerve may consist of these portions, one for each principal color.'

Dr. Young was avowedly not much given to experiment. He was an acute observer,

and highly original, but he avows: "For my part, it is my pride and pleasure, as far as I am able, to supersede the necessity of experiments, and more especially of expensive ones.'' Wollaston, in 1802, undertook his observations on the solar spectrum, using a prism of flint glass, a substance at that time comparatively new, hard to obtain in large pieces, and often blemished with veins. It is not surprising that his work should have been crude in comparison with that of the skillful optician, Fraunhofer, who a dozen years later rediscovered the solar lines and mapped them. Of the few lines discovered by Wollaston the most prominent were considered by him to mark the natural boundaries between the chief spectral colors. The *A* line, if we may here use Fraunhofer's notation, was thought by Wollaston to be the exact limit of the red; the *D* line to separate red from green; the *G* and *H* lines to be the natural boundaries of the violet. In Young's Natural Philosophy, published in 1807, he refers to the work of Wollaston, who, he says, 'has determined the division of the colored image or spectrum in a much more accurate manner than had been done before.' Referring to Wollaston's method, he adds: "The spectrum formed in this manner consists of four colors only, red, green, blue and violet." Referring to some of Newton's work in obtaining secondary hues he concludes: "We may consider white light as composed of a mixture of red, green and violet, only in the proportion of about two parts red, four green and one violet, with respect to the quantity or intensity of the sensations produced." In this volume Dr. Young makes no reference to the hypothesis of color perception which he had advanced in his Bakerian lecture a few years previously. Whether he had given it up or not is left to inference only. Despite his apparent indifference to experiments, he seems to have set the example, between 1802 and 1807, of appealing to the rotation of disks to show that gray may be obtained by the mixture of red, green and violet, quite as well as with Newton's seven colors, red, orange, yellow, green, blue, indigo and violet. He says: "The sensations of various kinds of light may also be combined in a still more satisfactory manner by painting the surface of a circle with different colors, in any way that may be desired, and causing it to revolve with such rapidity that the whole may assume the appearance of a single tint, or of a combination of tints, resulting from the mixture of the colors." Half a century seems to have elapsed before this fruitful method was taken up again by Maxwell and Helmholtz, and its valuable results have been still further extended by Rood, Abney and others.

When Helmholtz discovered the long-forgotten theory of Young he was professor of physiology at Heidelberg. The respect in which he is held by all physicists has very naturally caused them to repose confidence in the conclusions reached by him as a physiologist. This fact creates quite generally a prejudice in favor of the hypothesis of Young, which is accepted by them as a working hypothesis, even though its assumptions be far from proved. It has the merit of great simplicity. It can be grasped without any extended study of the technicalities of psychology. This is obviously no argument to prove its truth, but in the present condition of the subject, in the confusing multiplicity of color hypotheses and the apparent hopelessness of the struggle to establish anything definite that psychologists will agree upon as a substitute for the hypothesis which Helmholtz has offered to the physicists, simplicity with admitted uncertainty is for many of us preferable to the championing of a new hypothesis which is challenged by half a dozen other hypotheses supported by names of varying authority in the world of science.

What physicists need to be reminded of is the fact that Helmholtz's hypothesis is just as uncertain as some of the newer ones. Since the physicist, as such, deals only with the phenomena of color, and not at all with its specific effect on the brain, it can really make little or no difference with him what hypothesis, if any, of those now competing for supremacy shall win at last. But physicists cannot be expected wholly to withdraw their interest from subjects essentially separate but closely related to physics. It is of definite importance, therefore, that they should have some appreciation of the uncertainties which they may be tempted to treat as long established verities.

What, then, is a 'primary color,' or a 'fundamental color sensation?' Young seemed to think that a primary color is one of the minimum number whose mixture as lights produces white. This definition can hardly be accepted to-day. Physically there is no reason why any hue of given wave-length should be named primary in preference in some neighboring hue whose wave-length is slightly greater or less. The three primaries assumed by Maxwell were red, green and blue, the selection of wave-length for each standard being not definitely fixed. With the use of appropriate colored glasses for absorption in front of an electric lantern, the production of white on a screen by mixture of these three hues is easy enough. By the same method it is equally easy to produce white by the mixture of yellow and blue, or with any other pair of complementaries, such as red and the mixture of green and blue, which has been called peacock. If we take $\lambda = 0.58\,\mu$ for the yellow, and $\lambda = 0.47\,\mu$ for the blue, and thus succeed in obtaining white, the components of this, or of any other pair of complementaries, may be thus called primaries. Or, if we mix peacock, purple and yellow, which are the complementaries of red, green and blue, respectively, the white attained is quite satisfactory. If a triplet of colors be deemed necessary, therefore, peacock, purple and yellow may be called the primaries, though it might be harder to designate the purple by any single wave-length. It is thus quite indefinite to speak of a primary as one of a minimum number of hues whose mixture produces white.

A primary has been otherwise defined as a hue which is incapable of being produced by the mixture of any other two hues. Red is thus called a primary, while yellow is distinctly not such. But the yellow due to a mixture of red and green is always deficient in purity, and a similar comment may be made upon the result of any color mixture. If violet be called a primary, as one of Young's triplet, it may be replied that by suitable mixture of red and blue a violet may be obtained that is quite as good of its kind as the yellow obtained by mixing red and green. If blue be called a primary, as one of Maxwell's triplet, it may be replied that by suitable mixture of peacock and violet a good blue may be produced. If green be called a primary it may be produced, though with considerable admixture of gray, by mixture of peacock and yellowish green. It thus appears that red is about the only hue to which this definition seems to be fully applicable. Admitting it, therefore, as a primary, the selection of its companion primaries is still uncertain.

Whatever may be the definition finally agreed upon for 'primary color,' the corresponding sensation is the 'fundamental' sensation. A very large amount of time and labor has been spent in the effort to obtain curves that shall correctly represent these fundamental sensations. The curves as estimated by Helmholtz are shown in Fig. 1, and have long been familiar. In the figure they are adjusted, not to the prismatic, but to the normal spectrum. It is seen that the maxi-

mum for the red is in the brightest part of the spectrum affecting the eye as red; it would ordinarily be called scarlet. The maximum for violet is likewise in the brightest part perceived as violet; it would be called a bluish violet, or almost ultramarine. The maximum for green is in the brightest part of the green. Maxwell's curves, obtained experimentally by use of his color-box (Phil. Trans., 1860), differ from those estimated by Helmholtz. The maxima for red and green are each shifted very decidedly toward the yellow, while that for the violet is in the typical blue.

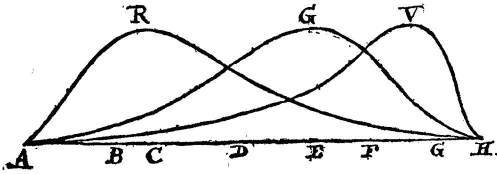

Fig 1.

An elaborate investigation was undertaken, under the direction of Helmholtz, by Koenig and Diderici, and published in 1886. (*Sitzungsberichte der Koeniglich Preussischen Akademie der Wissenschaften zu Berlin*, 22 Juli, 1886.) This was based on the examination not only of those having normal eyes, but of several persons with different grades of color-blindness. No English translation of this paper has thus far been published, and it is to be regretted that some parts of it are wanting in clearness, if judged by American standards. The collective color equations were deduced from observations with a Helmholtz color-mixing apparatus, but the reader is informed that "the experimental details demand for their representation so much space that we cannot here go into them." The final result is shown in the curves of Fig. 2, which should be compared with those of Fig. 1. It is seen that the violet curve extends here from the H line only to the D line; that the green curve extends into the violet and red regions, but by no means to the ends of the spectrum; and the red curve reaches but little beyond the F line in the blue. The violet maximum is

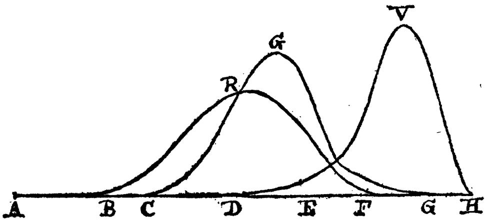

Fig 2.

at $\lambda = 0.445\,\mu$, corresponding to ultramarine. The green maximum is at $\lambda = 0.545\,\mu$, corresponding to a yellowish green. The red maximum is at $\lambda = 0.564\,\mu$, which corresponds not to red, orange, or even pure yellow, but to a slightly greenish yellow. This is so wide a departure from the earlier ideal curve of Helmholtz, and from Maxwell's result, that one is tempted to ask whether there may not have been some very arbitrary assumption involved in the deduction of one or the other. The overlapping of the curves emphasizes the well-known fact that even the most nearly pure of spectral colors near the middle of the spectrum are decidedly impure. Taking account of this fact, the authors reach the conclusion that the pure fundamental sensations would correspond to hues about as follows: for red, $\lambda = 0.671\,\mu$, which is near the red end, between the B and C lines, instead of the maximum, of the red curve; for green, $\lambda = 0.505\,\mu$, a slightly bluish green, which is close to the intersection of the green and violet curves, instead of the maximum of the former; and for violet, $\lambda = 0.470\,\mu$, a pure blue, which is decidedly nearer the middle than is the maximum of this curve. The reader is not favored with the calculations by which these wide differences are found between the curve-maxima and the spectral positions corresponding to the fundamental sensation hues.

In the construction of the curves by Koenig and Diderici it should be observed that the areas are made the same. Red, having the greatest extent of different wave-lengths included in the sensations, has the least height. Violet, having the least extent, has the greatest height. The corresponding ordinates, therefore, must not be confounded with the ordinates representing relative brightness. Of all the spectrum colors violet has the least brightness. The proper distribution of ratios for brightness is shown in Fig. 3, which is due to Captain

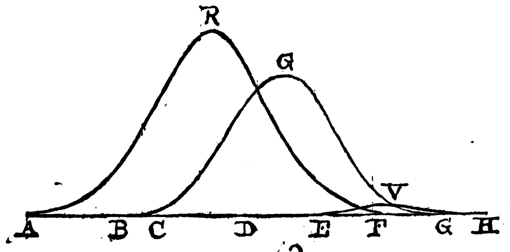

Fig. 3.

Abney, and made from very careful observations with his 'color-patch' apparatus after the publication of the work of Koenig and Diderici. They agree quite well with Rood's results obtained twenty years ago, so far as brightness is concerned (Modern Chromatics, p. 34). These curves additionally show maxima quite different from the ones just discussed. Abney's red maximum is between the C and D lines, corresponding nearly to scarlet; his green maximum in the yellowish green, and his violet maximum in the blue; all of which seems much more consistent than the result obtained by Koenig and Diderici.

In the face of these diversities between the results of highly skilled observers, all of whom have assumed the truth of the Young and Helmholtz hypothesis, it may, perhaps, be asked whether physical investigation of this difficult subject has settled us upon much firmer ground than that occupied by the opponents of this hypothesis. The history of the idea of primary colors shows that scientific precision has not been its chief characteristic. We are perfectly sure that there are some hundreds or thousands of different hues represented by different wave-lengths which produce effects upon the retina, no one of which has any better claim than any other to be considered primary. As a matter of convenience there are certainly great advantages to be derived from suitable grouping of these wave-lengths, but it may be well questioned whether there is any physiological or psychological basis for such grouping. If it is only a matter of convenience has there not been an enormous amount of labor expended in the attempt to find a foundation that is only imaginary? The phenomena of color-blindness are the ones of most importance in this connection. Red blindness is the most common, green blindness almost equally so, and violet blindness so rare that it is in practice hardly taken into account. A glance at Abney's curves shows that this is what ought to be expected. But deficiency of color sense for red is often accompanied with less marked deficiency for yellow, green and blue, and there seems no good reason for considering any one of these deficiencies more fundamental than any other. We may continue to use the color-sensation curves, and find that, instead of indicating uncertainty about the true hues of primary colors, they merely show natural diversity among the different individuals subjected to examination. We may still use the Young and Helmholtz hypothesis as the simplest and most convenient representation of color phenomena, but with large reservation and prudent silence about primary colors. These we may rightly call prominent colors, while we profess our total ignorance about the way in which they affect the retina or the brain. This condition of somewhat discon-

tented ignorance we can maintain until our friends, the psychologists, finally settle upon some one theory after this is fortified with evidence of such a character as to exclude its competitors. Their authority will then be accepted as readily as they now accept the authority of the physicists about the polarization of light or the mechanical equivalent of heat.

So far, therefore, as physicists accept the Young and Helmholtz hypothesis their acceptance must be based, not on any physiological grounds, but upon its convenience of application to the phenomena of color mixture and color analysis. Practically, one hypothesis may, perhaps, be no better than any other for this purpose, If we abandon the term 'primary color,' and substitute 'prominent color' for it, our selection may be determined avowedly by convenience. In the performance of the extended work of color analysis, which was undertaken a few years ago under the direction of Professor Rood for a well-known firm of publishers, the composition of all compounds was expressed in terms of black, white and five 'standard colors,' red, orange, yellow, green and blue. The standard pigments selected were English vermilion, mineral orange, chrome yellow, emerald green and artificial ultramarine, all of which give enduring and reliable hues. Violet was left out because no sufficiently reliable pigment was obtainable; but by mixture of appropriate proportions of standard red, blue and black a good violet was included in a selected series of types. There is no danger of practical inconvenience to the physicist because of the present unsatisfactory conditions relating to color theory.

To give the outlines of the competing views is hardly necessary. The Hering hypothesis is well known, and probably universally rejected among physicists. Wundt's hypothesis has a good following among psychologists, but is still very little known among physicists. Without pretending to be a psychologist, I am much more favorably impressed with this hypothesis than with that of Hering. Mrs. Franklin's views need not be outlined, as they are readily accessible, in either the English or German language. With the hypotheses of Ebbinghaus and Nicati I have not yet become acquainted. Physicists will, perhaps, not be surprised at this frank confession.

W. Le Conte Stevens,
Rensselaer Polytechnic Institute,
Troy, N. Y.

THE EPARTERIAL BRONCHIAL SYSTEM OF THE MAMMALIA.

The paper deals with the structure of the bronchial system and pulmonary vascular supply of the mammalia as exhibited by corrosion in an extensive series comprising representative types of all orders and many families. The conclusions reached are, in the main points, at variance with the views expressed by Professor Aeby and generally accepted in the current text-books of Human and Comparative Anatomy. For reasons given in detail in the paper, the primitive form of the mammalian bronchial distribution appears to be Aeby's 'bilateral hyparterial type.' The arrangement of the primary bronchial trunks and of the pulmonary artery exhibited in this type is of considerable morphological importance in reference to the evolution of the typical mammalian bronchial tree, and is discussed at length in the paper. Aeby's researches revealed but a single form possessing this distribution, viz.: *Hystrix cristata*, the European Porcupine. Subsequently, M. Weber described the same type in the lungs of *Balæna mysticetus* and *B. antipodum*. The present investigations have added a fourth form to the list, *Taxidea americana*, the American Badger.

In examining the lungs of the remaining